Measurement and Simulation Results on 157 nm Transmission in N_2 Purged Hard Pellicle – Mask systems

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157 nm Pellicle Reticle Purge Update

Outline

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157 nm Pellicle Reticle Purge Update

Background

- 157-nm lithography is the leading candidate beyond 193 nm lithography
- O_2 strongly absorbs 157nm light so mask-pellicle has to be purged
- One of the most critical issues for mask handling is to develop an efficient *in-situ* N_2 purge structure
- For hard pellicle system, purge can be slow and lengthy, which is prohibitive for HVM
- Intel has conducted purge study with experiments and CFD model
- The purpose of this presentation is to report Intel's learning in this area

157 nm Pellicle Reticle Purge Update

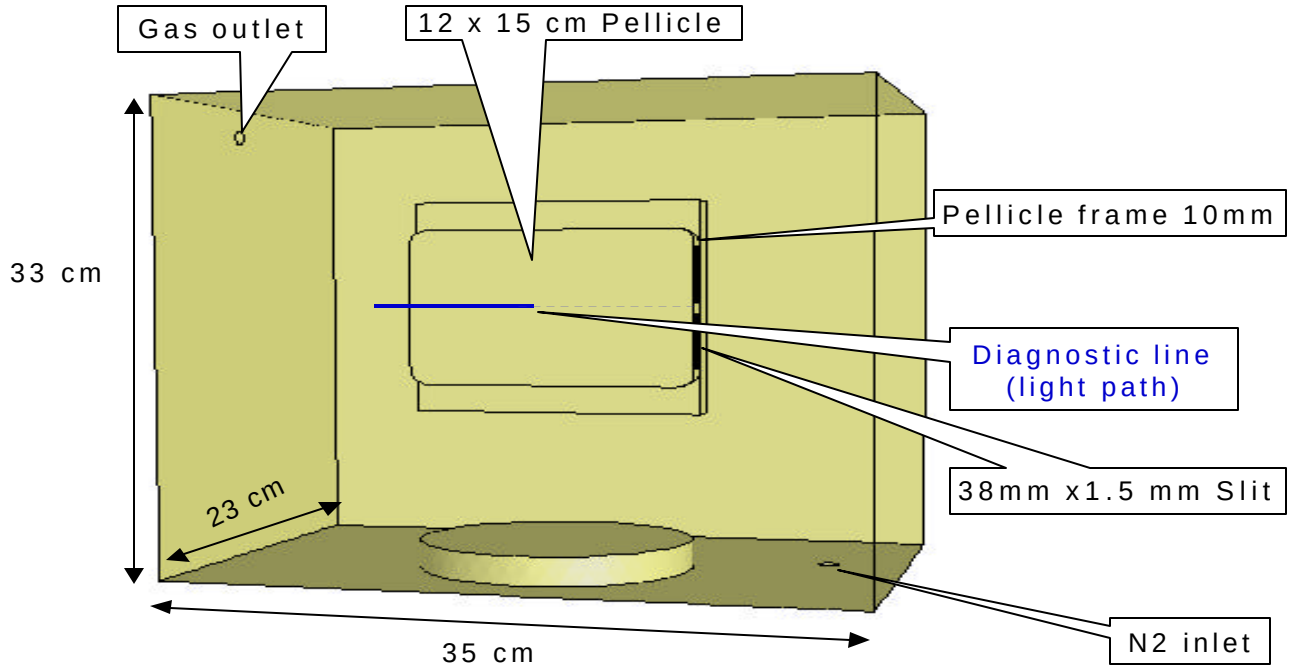
There are two basic modes of purging

- Diffusive or passive purge - reticle system is merged in a much larger purged chamber. There are vent holes to let N_2 flow through the reticle system.
- Convective or active purge - reticle system is directly connected to N_2 flow. Pressure gradient across purge holes pushes N_2 through.

Experiment - Passive purge

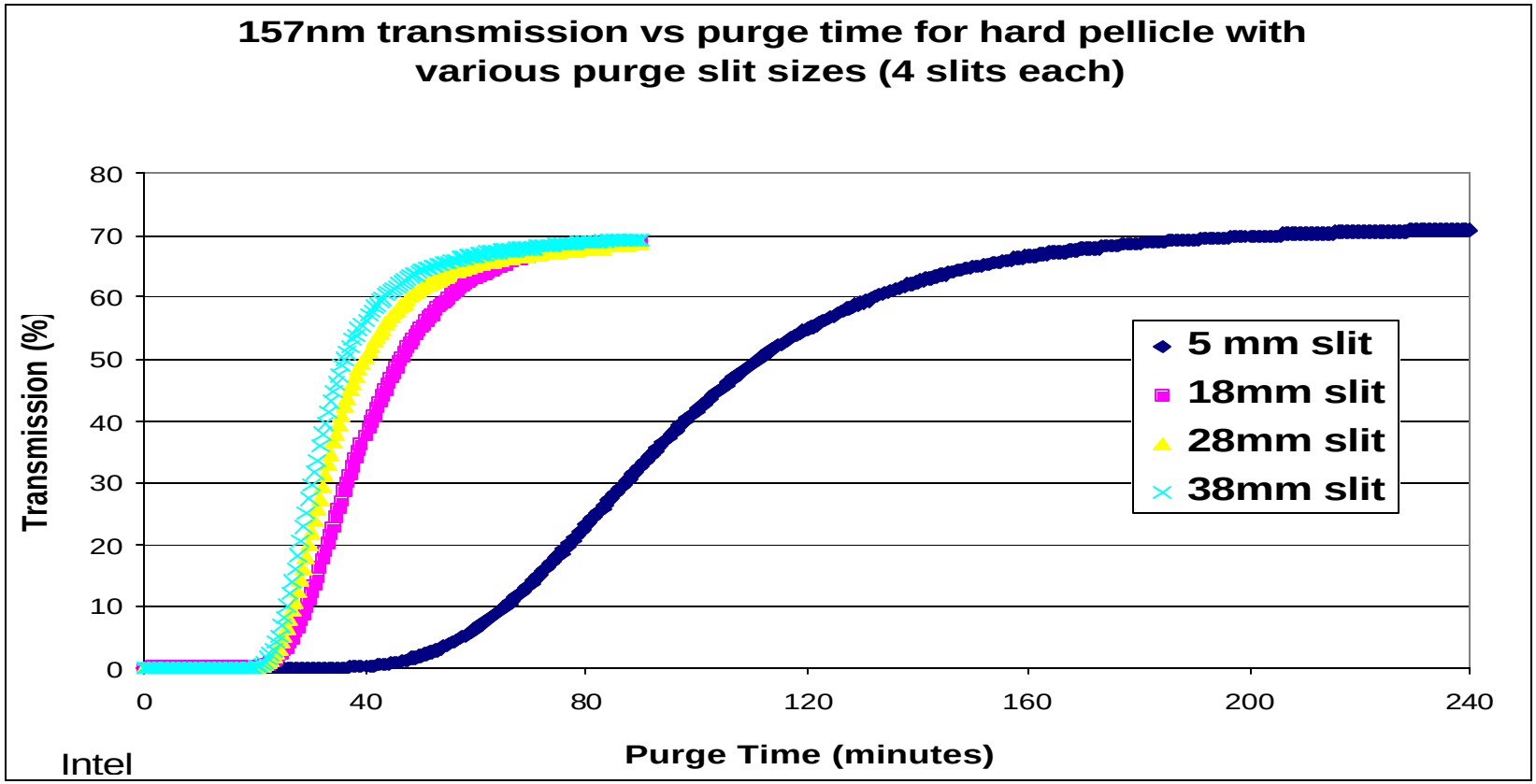
Diffusive/Passive purge:

- Mass flux: $\Gamma_{pass} = -\lambda\, dn/dx \;>> nv$



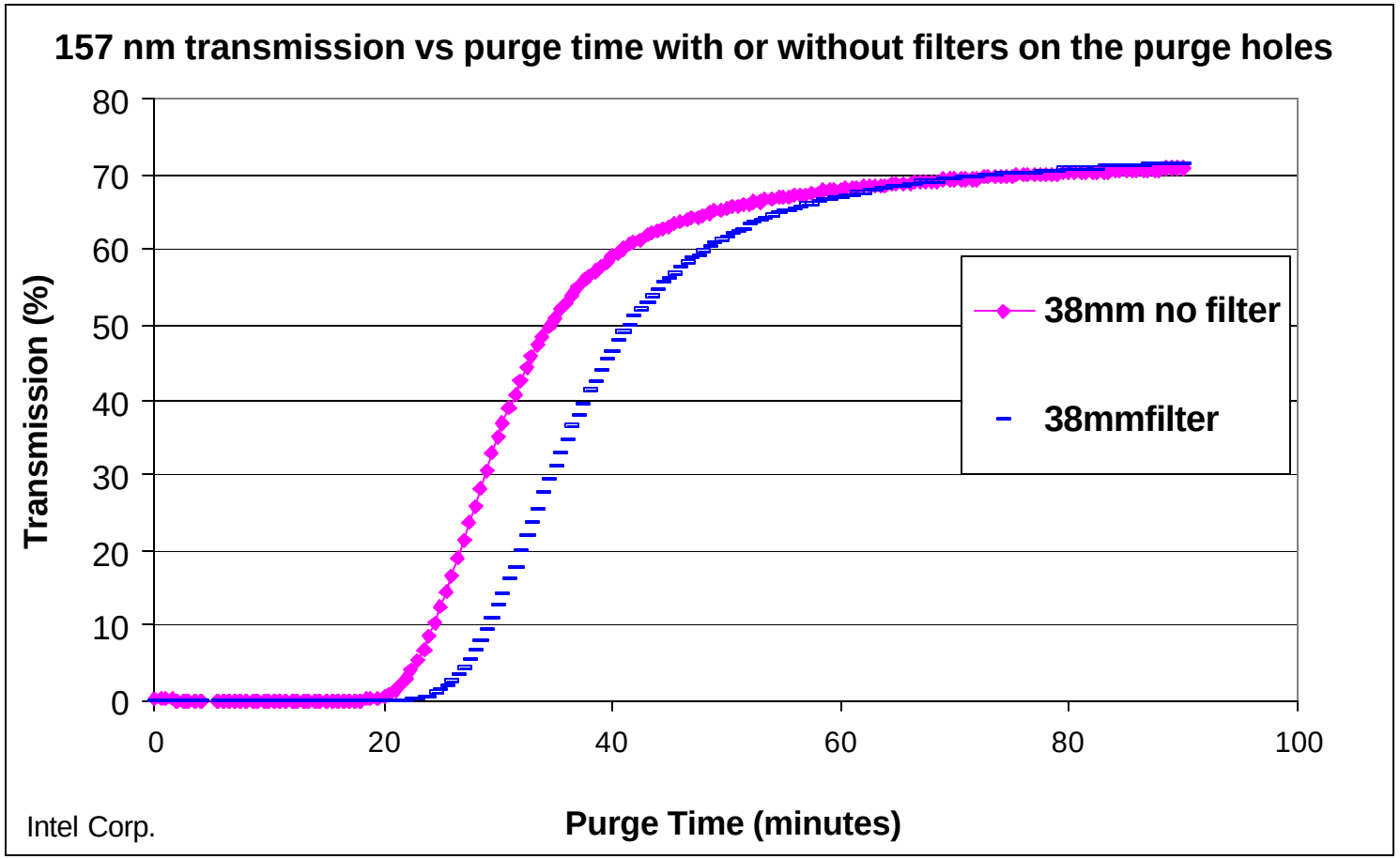
Experiment Results – Passive purge (no filters)

- Purge dynamics depends strongly on variables such as purge slit size, gas flow rate, geometry, etc.



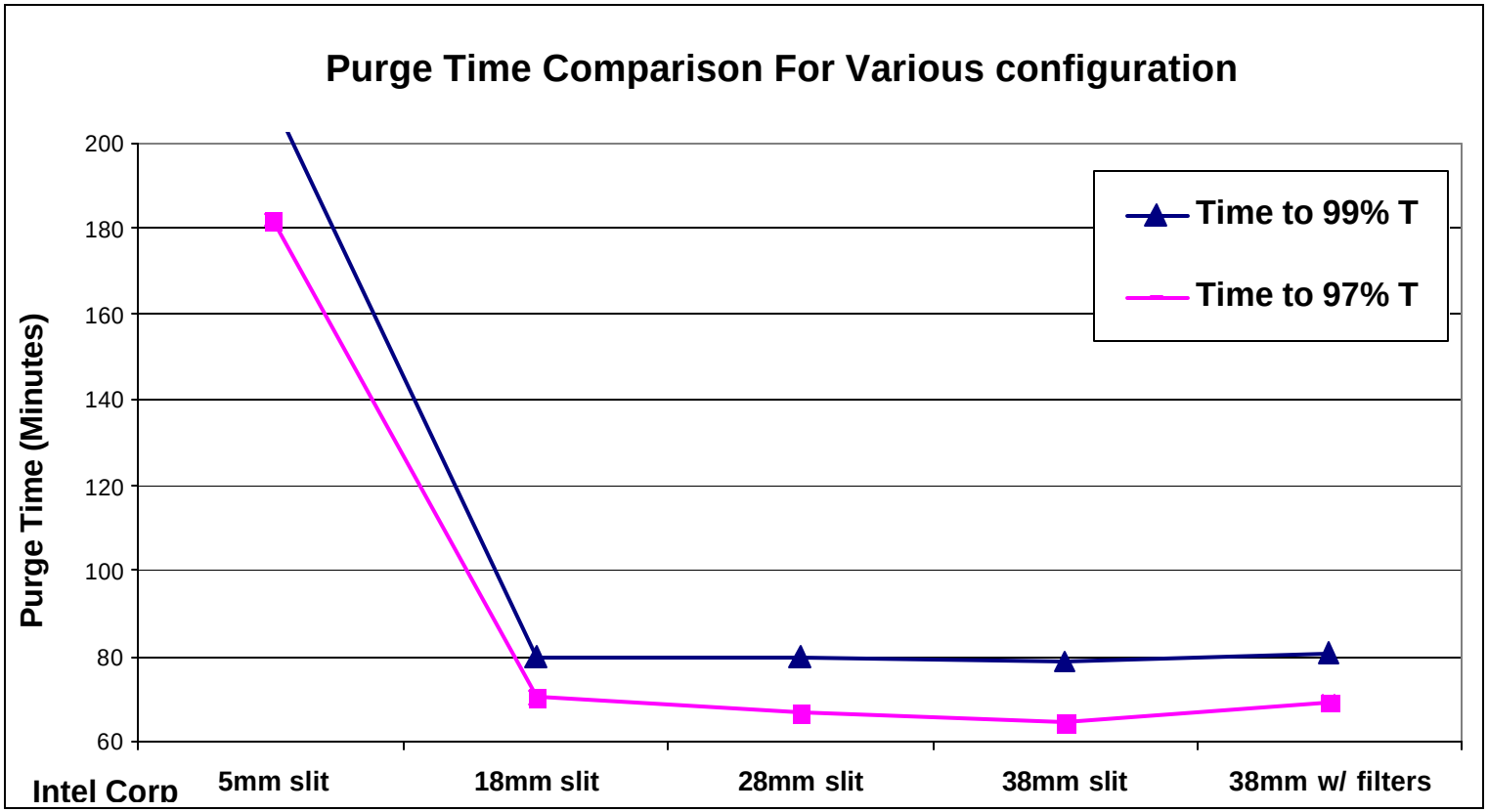
Experiment Results – Passive purge (w/ or w/o filters)

- If particle filters are used on the vent slits, purge is slower initially



Experiment Results – Passive purge summary

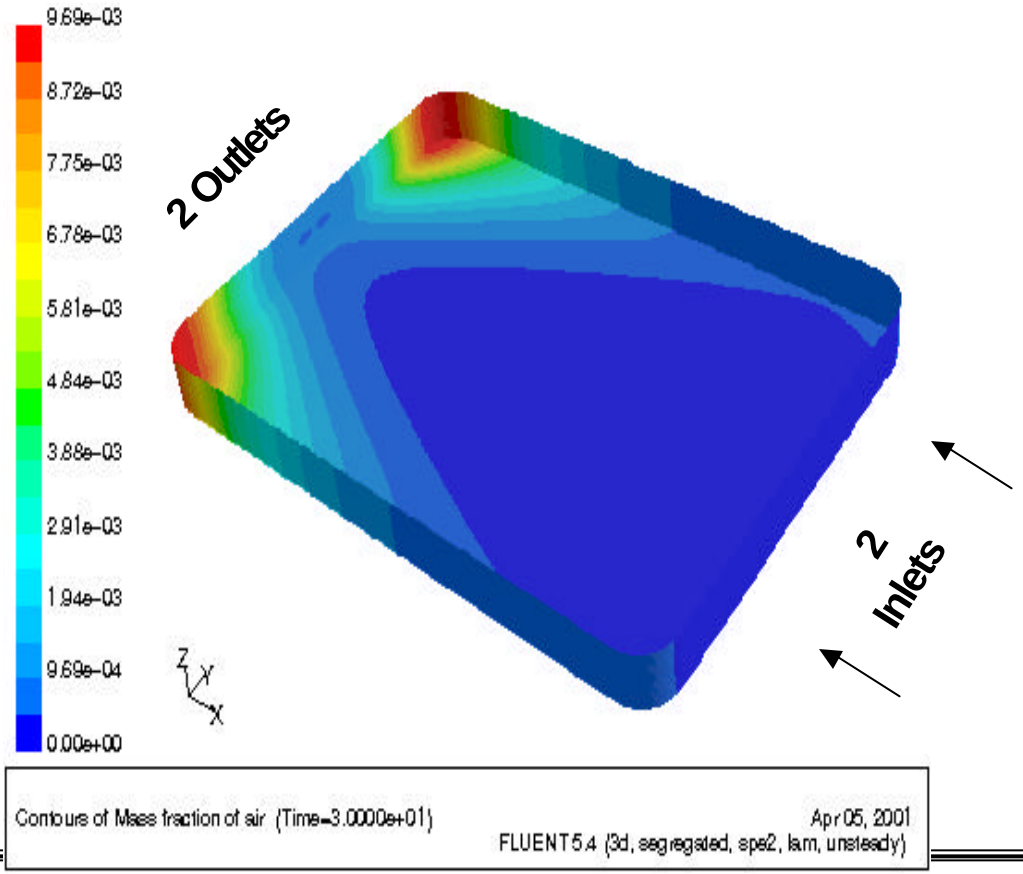
However, purge time to 157nm operating condition has little dependence on those variables (once reach above-threshold conditions)



Simulation - Active purge

Convective/Active purge

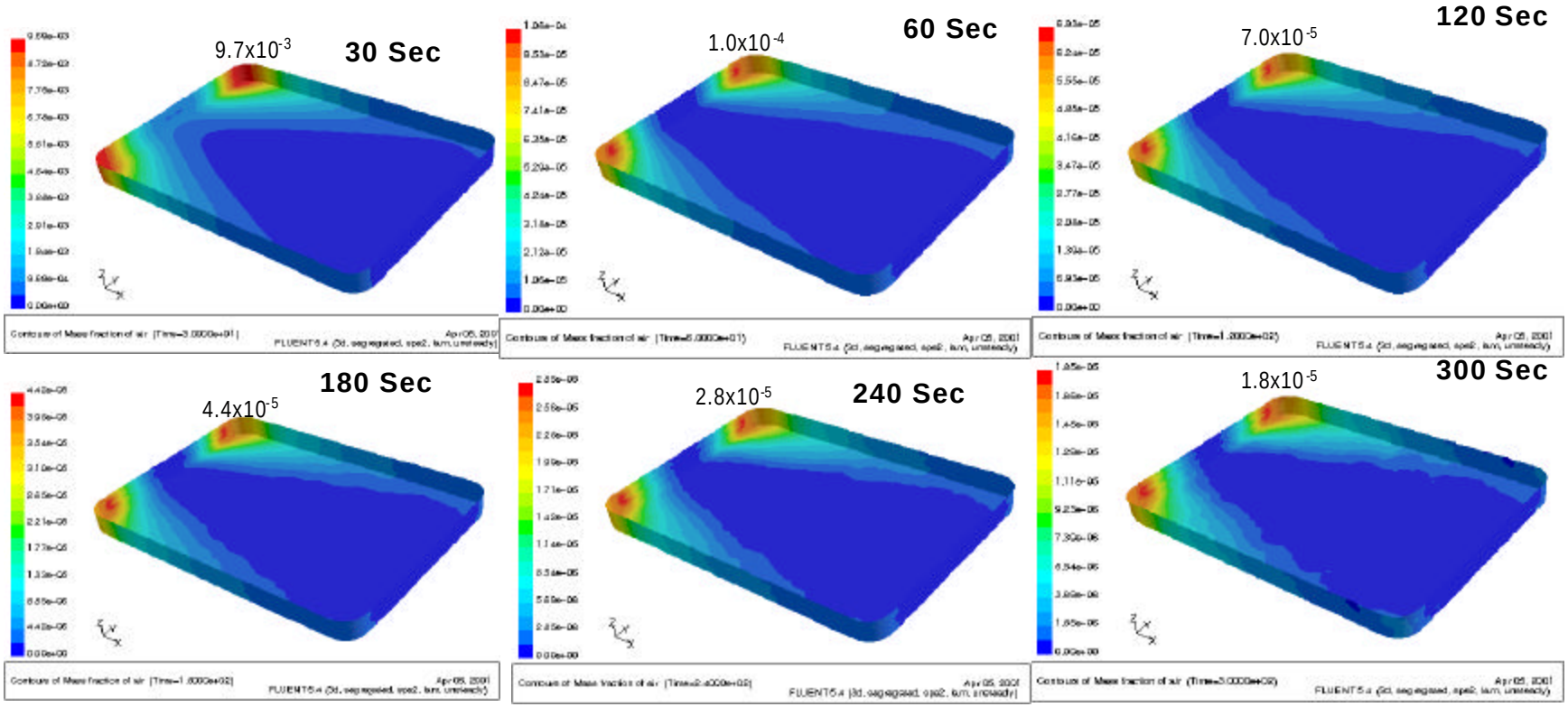
- Mass flux: $\Gamma_{act} = nv >> -\lambda\, dn/dx$



Simulation Result
- Active purge process (2x38mm inlets)

- Design of purge box must constrain N_2 flow directly under pellicles
- Dead zones at the corners stay for a while, need to optimize slit distribution to minimize

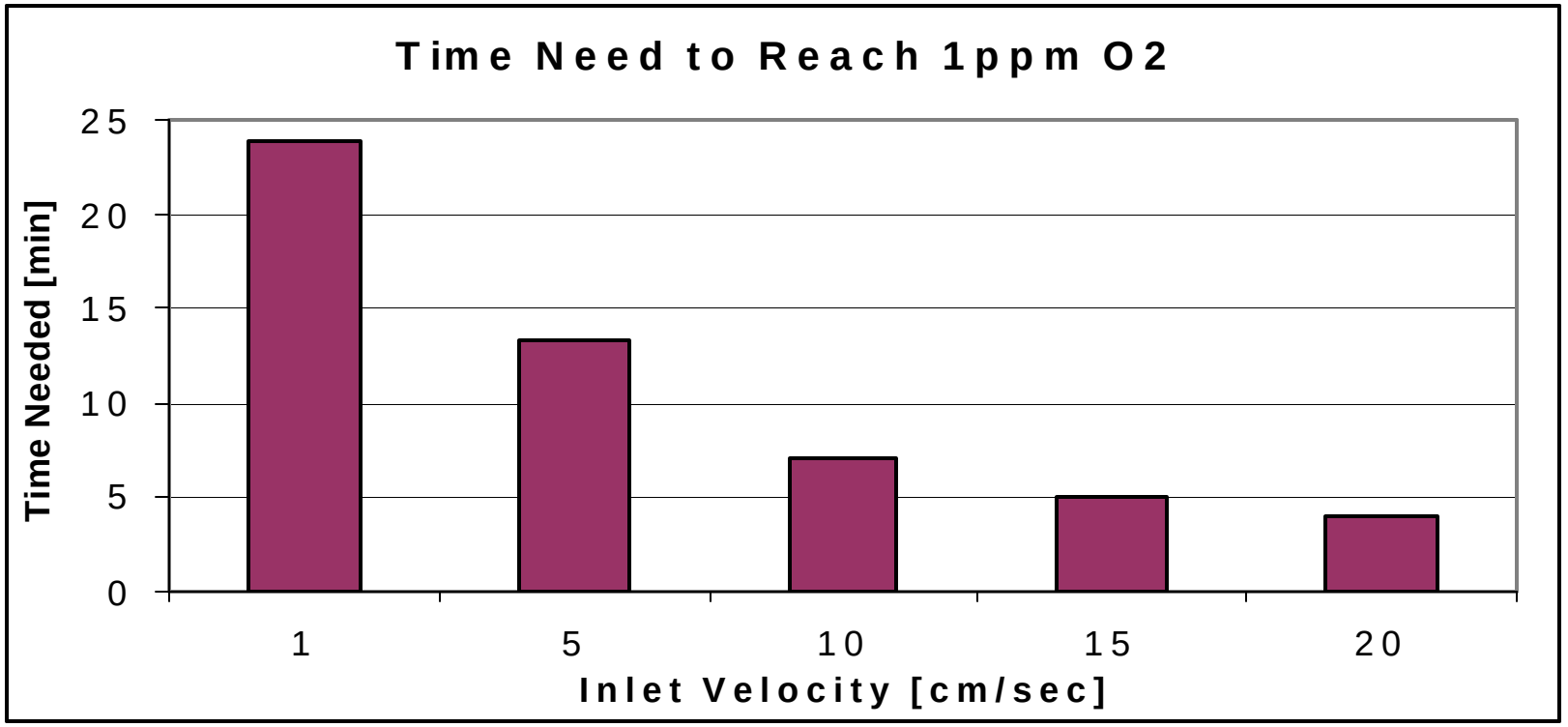
Air Mole Fraction in Time Sequence



15 cm/s N2 gas inlet from 38 x1.5 mm slits (1026 sccm)

Simulation Result – Active purge time (2x38mm slits)

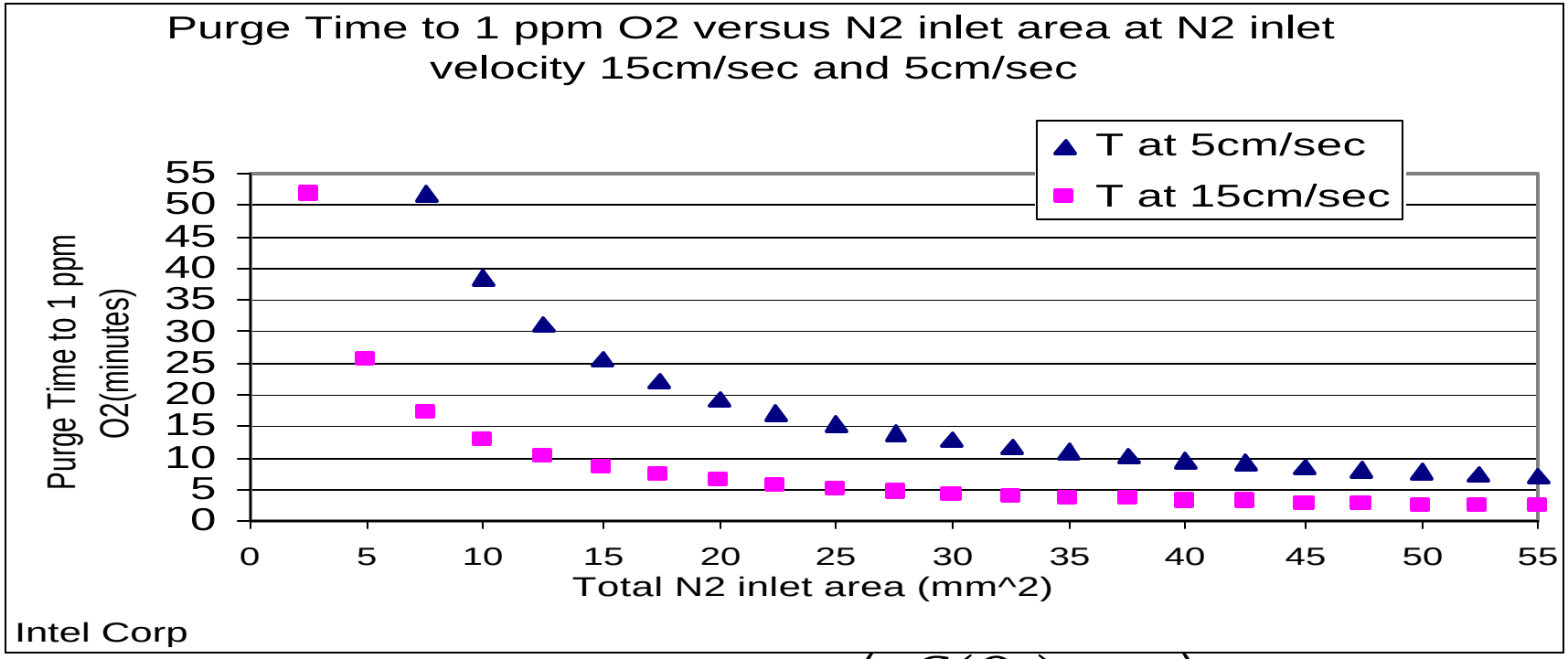
- Purge time can be in minutes
- High mass flow shortens purge time



Simulation - Active purge parameters

Two critical variables: gas flow velocity and purge inlet area (all other parameters are fixed by spec)

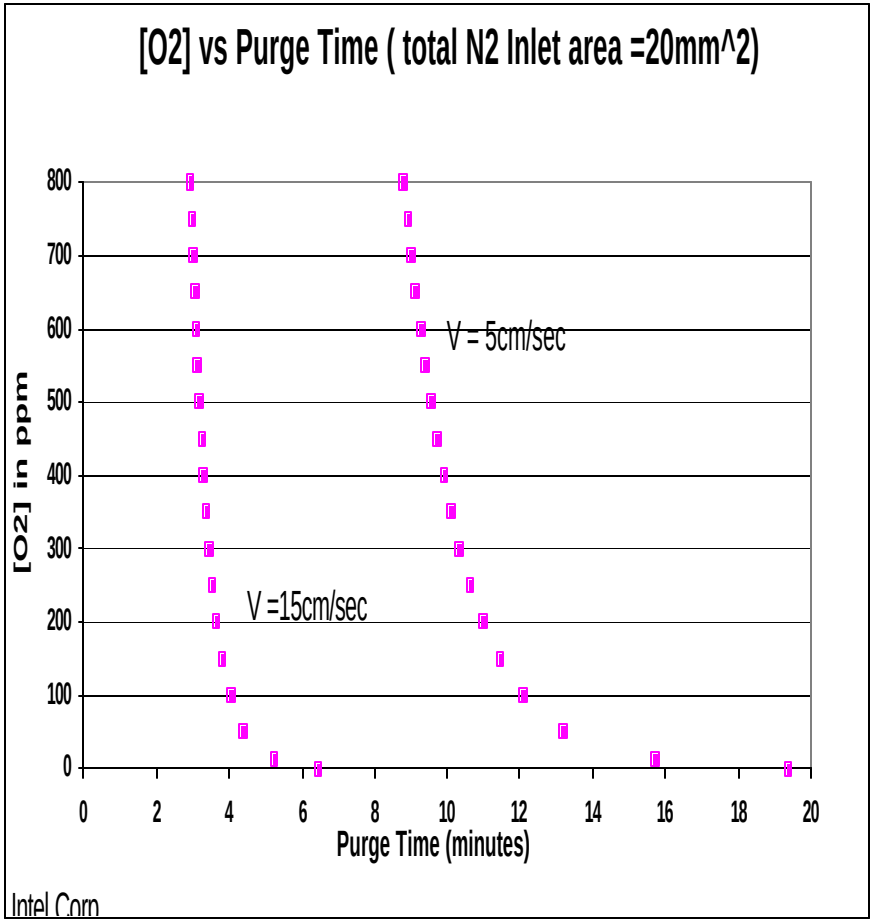
- Face velocity V_f across vent filtration: $V_f \uparrow$ $T_p \downarrow$
- Total inlet area: Larger area allows shorter time up to saturation pt.

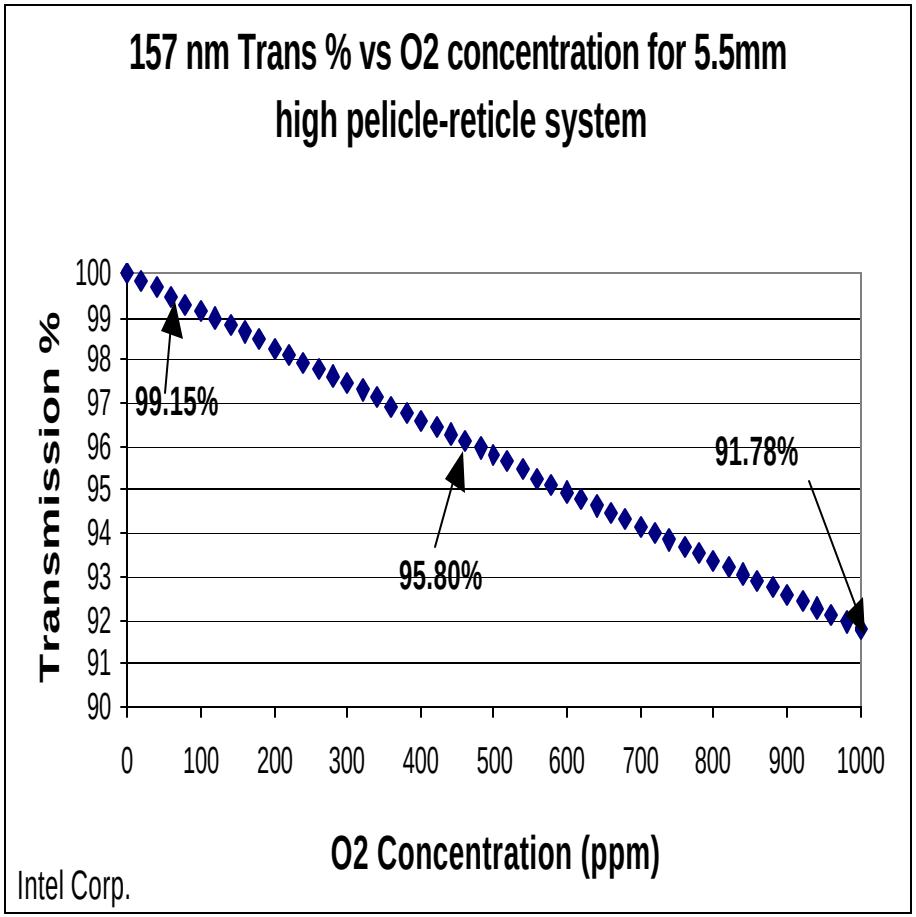


$$t_{purge} = -\frac{Volume}{Flowrate} \ln\left(\frac{C(O_2)_{final}}{C(O_2)_{ambient}}\right)$$

Simulation - Active purge
(trade-off between purge time and throughput)

- will be decided by Spec requirement of operating O_2 concentration



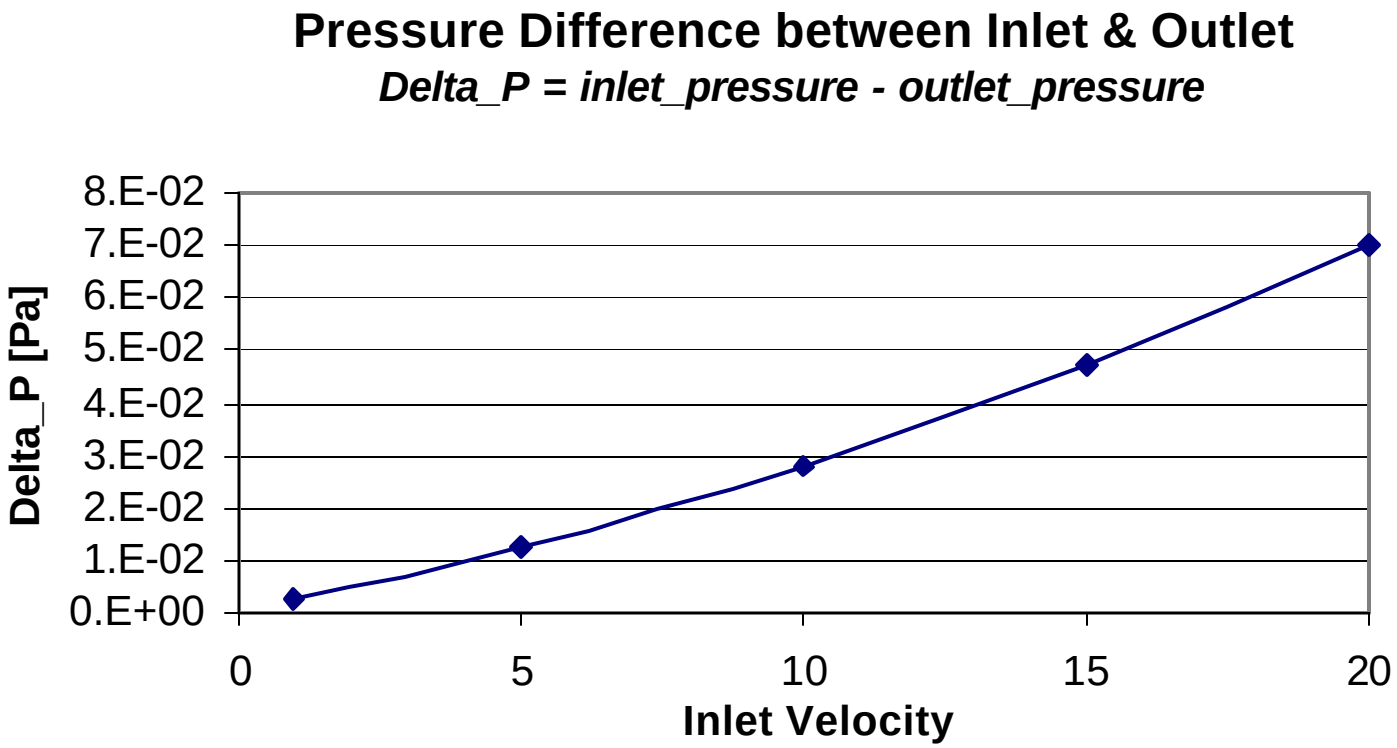


Summary and Conclusion

Extensive study on hard pellicle system purge through experiments and CFD simulation conducted at Intel came to important guidelines for mask purge solutions:

- Passive purge alone is not efficient
- Passive purge time depends very little on purge hole design at low O_2 level
- Active purge can be fast and in minutes
- Active purge time depends on purge inlet area, flow speed, and O_2 operation spec.

Attachment 1
Pressure Gradient and Inlet Velocity Correlation(Active purge)



Attachment 2
Mechanical considerations in Active Purge

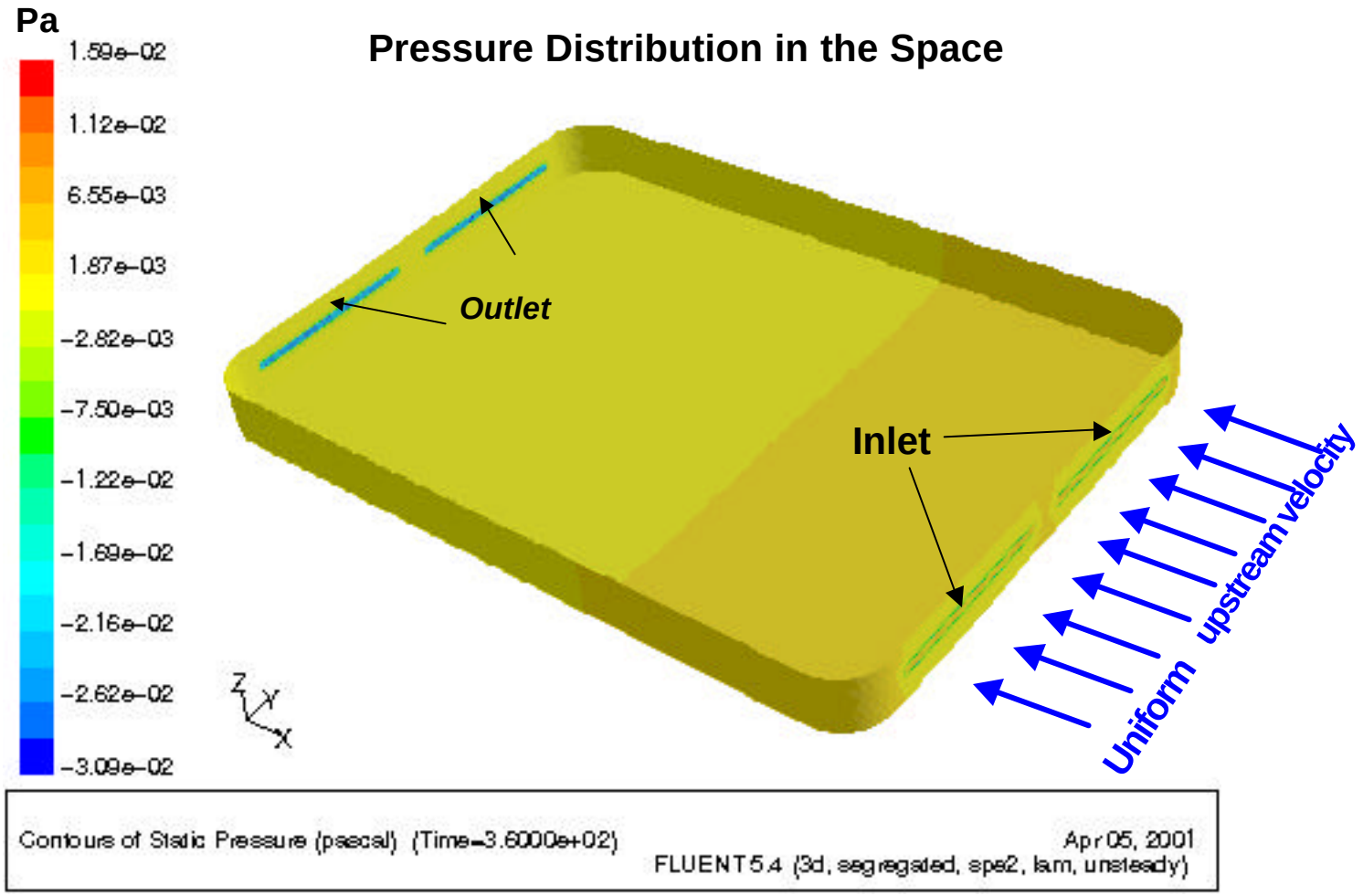
Active purge induced force, deflection, and resonance on hard pell

- Total distributed force = delta_P x pell area
 @15cm/sec, delta_P= 5×10^{-2} Pa, pell area=172×10^{-4} m^2
 total force=0.86 mN
- Deflection at center of 300 µm pell =0.10 µm
- Deflection at center of 800 µm pell =$0.10 \times (300/800)^3$ =0.005µm

(Deflection calculated by Prof. Ed. Lovell from Uni.Wis. ME.)

- Resonance frequencies
 Natural frequencies of 300 µm pell-reticle are 170Hz, 220Hz, 310Hz…-measured and simulated by Uni.Wis CMC group.

Attachment 3
Other parameters in Active Purge



Attachment 4
Other parameters in Active Purge

Purge time [min] to reach 1 ppm O2 concentration

For 96 cm3 space to purge to 1 ppm O2

	Open Ratio=0.1	0.3	0.5	1.0
Inlet Area 30 mm²				
Upstream velocity [cm/s] = 5	269	90	54	27
10	134	45	27	13
15	90	30	18	9
Inlet Area 50 mm²				
Upstream velocity [cm/s] = 5	161	54	32	16
10	81	27	16	8
15	54	18	11	5
Inlet Area 100 mm²				
Upstream velocity [cm/s] = 5	81	27	16	8
10	40	13	8	4
15	27	9	5	3